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2.	Patent application number *(The Patent Office will fill in this part)*	13 JAN 2001 **0100989.3** 15JAN01 E598012-1 D02835 P01/7700 0.00-0100989.3
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Filterwerk Mann + Hummel GmbH Hindenburgstrasse 45 D-71638 Ludwigsburg Germany
	Patents ADP number *(if you know it)*	00448571006
	If the applicant is a corporate body, give the country/state of its incorporation	Germany
4.	Title of the invention	Centrifugal Separation Apparatus
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	URQUHART-DYKES & LORD GREG'S BUILDINGS 1 BOOTH STREET MANCHESTER M2 4DU
	Patents ADP number *(if you know it)*	00001644014
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DUPLICATE

Centrifugal Separation Apparatus

This invention relates to centrifugal separation apparatus for separating particulate contaminants from liquids, such as engine lubricants, passed therethrough to effect cleaning, and in particular relates to rotor means used within such apparatus to perform the actual separation and retention of such contaminants.

Centrifugal separation apparatus is well known for use within the lubrication systems of vehicle internal combustion engines as efficient means for removing very small particulate contaminants from the constantly recirculated liquid lubricant over a long period of operation, such particulate contaminants arising from abrasion of the metallic components of the engine, decomposition of the lubricant and products of combustion.

Insofar as such separators are responsible for cleaning a liquid which is in any event circulated at elevated pressure, the art has concentrated on employing such lubricant pressure to effect rotation of parts responsible for generating centrifugal forces, and as such it includes rotor means comprising an essentially closed vessel, or canister, being supported for rotation about a rotation axis within a housing, and supplied with the liquid lubricant at elevated pressure at the axis. The canister is filled with the liquid and assumes a significant internal pressure before liquid is forced from the base (or other peripheral wall) of the canister by way of tangentially directed jet reaction nozzles, the reaction to said ejection causing the rotor canister and liquid within it to spin at high speed about the axis and thereby force solid particles to migrate from the liquid passing through the canister and agglomerate into a cohesive mass on the peripheral walls spaced from the rotation axis. The reaction nozzles, being directed substantially tangentially with respect to the rotation axis, at least in a plane orthogonal to the axis, define a reaction turbine.

It will be appreciated that the efficiency of separation is inter alia dependant upon creating the conditions in which any liquid entrained particle can migrate radially to the nearest deposition surface and is a function of the force acting on such particle and the time for which it can act. The former is a function of rotation rate and distance from the rotation axis. The latter is a function of the time taken for the entraining liquid to pass through the rotor canister (also called the dwell time) and the proximity of the deposition surface, and may be considered in terms of an effective dwell time, that is, influencing the contribution of the actual dwell time by positioning the contaminated liquid relatively to an appropriate deposition surface. However

both the rotation speed of the rotor canister and contained liquid, and the rate at which liquid is passed through and ejected therefrom, are dependant upon the pressure drop between the canister contents and housing and upon the dimensions of the nozzles, within the constraints of such nozzle dimensions providing sufficient torque from the turbine to overcome inertial and frictional resistance to commencement of, and continuation of, rotation.

Within an internal combustion engine where lubricant is circulated under an initial (pumped) pressure in a range of about 2 to 6 bars that varies with operating conditions, a canister of relatively modest diameter, say 10 to 15 cms, and reaction turbine nozzles may achieve a rotation speed in the range of 4000 to 9000 r.p.m. which is sufficient for removing the relatively dense, contaminants of lubricant residue and metallic particles traditionally considered to be of principal detriment to the engine.

Examples of such reaction turbine centrifugal separation are shown in GB 745377, GB 2328891, US 5575912 and US 5906733, and it can be seen that as developments have been made to increase efficiency of separation, and range of separability, the degree of structural complexity has also increased, not least in optimising effective dwell time and/or placing the liquid to maximise forces acting upon entrained contaminants for the limited rotation forces available.

This is particularly true in respect of the dual goals of deriving maximum rotation energy from the liquid passing through the rotor whilst providing therein conditions necessary and suited to centrifugal separation of low density contaminant particles such as soot. Such contaminants are now seen as an important cause of engine wear, particularly in compression ignition engines, and require the lubricant to be provided with greater effective dwell time and/or be subjected to greater centrifugal forces than hitherto, notwithstanding that providing such conditions in these arrangements also tend to militate against efficient flow of liquid through the canister.

Obtaining greater rotation rate from such a reaction turbine necessitates ejecting liquid at a greater rate, by increasing the pressure and/or by shortening the dwell time or by increasing the volume of liquid contained, whereas attempting to cause the contaminant entraining liquid to traverse the canister at a greater radial distance from the axis is made difficult by the fact that the rotating liquid content of the canister creates a radial pressure gradient tendering to keep newly introduced liquid away from the radially outer region of maximum centrifugal force

(unless internal structures are provided that add to the complexity and/or consume energy from the rotation). Therefore, optimising such rotor canister is not a matter of simply increasing the radial dimensions of the canister but effecting a compromise that nevertheless includes containing within the canister at high pressure a relatively large volume of the liquid lubricant to enable it to have a significant effective dwell time whilst it follows a tortuous path that involves interchanging potential and kinetic energy until it is ejected with sufficient energy for rotation production.

US 6017300 in particular explains in some detail that for properly separating very lightweight soot particles that can contaminate the liquid lubricant as products of combustion, the particles have to be subjected to higher centrifugal forces than readily available from such traditional, reaction turbine drive centrifugal separation arrangements, along with a longer dwell time, and proposes to elaborate upon the complex cone stack arrangement of US 5575912 by an external impulse turbine, the latter providing for high rotation operation and, being separate from the liquid for cleaning in the container, permits the contaminated liquid to have a longer dwell time.

Separating low density contaminants from constant streams of high pressure liquid is not the only situation for which traditional centrifugal separator designs are inadequate. For example, as described in US 5906733 where the liquid to be cleaned is derived only indirectly from a high pressure circulation, either at low pressure or intermittently, a separate flow of the high pressure liquid is employed to effect rotation of the canister whilst the liquid to be cleaned can flow through at lower pressure and/or at lower rate, the separate flow of liquid effecting rotation by way of direct reaction jet nozzles in the container or as an impulse turbine employing external blades against which liquid is directed from stationary nozzles.

Insofar as these modified designs still adopt the principle of defining a rotor vessel whose radial dimensions are optimised for centrifugal forces on liquid entrained particles and function by filling it with the contaminated liquid and then effecting rotation at appropriate speed, they still exhibit significant rotor vessel inertia and have to provide energy to overcome frictional and other bosses, providing a slow response, particularly in start-stop situations.

It is an object of the present invention to provide centrifugal separation apparatus suitable for separating low density particulate contaminants from circulated lubricant of an internal combustion engine which mitigates disadvantage of known designs.

It follows that any centrifugal separation apparatus which effectively separates low density contaminants is also able to separate relatively high density contaminants mixed therewith.

According to the present invention centrifugal separation apparatus for separating solid contaminants from a liquid comprises
a housing into which extends inlet duct means for supplying contaminated liquid thereto at elevated pressure and outlet duct means for drainage of cleaned liquid therefrom,
rotor means, mounted within the housing for rotation about a rotation axis extending through the housing, and
drive means operable to spin the rotor means about the rotation axis,
the rotor means comprising a walled separation and containment vessel having an impervious radially outer side wall extending about and along the rotation axis forming radially inwardly from the side wall an annular contaminant separation and containment zone, outlet passage means leading externally of the vessel to within the housing, and inlet means operable to convey liquid to be cleaned from the housing inlet duct means to the contaminant separation and containment zone, and characterised in that
the annular contaminant separation and containment zone is bounded radially inwardly of the said outer side wall by the outlet passage means and the inlet means is arranged to convey liquid to the zone at a lesser rate than is capable of draining therefrom such that the liquid and contaminants separated therefrom are confined in the vessel to the annular zone.

Preferably the drive means comprises fluid motor means, which fluid motor means may be driven by liquid at elevated pressure. The liquid may be the liquid to be cleaned. That is from the same source, or may be the liquid that is actually cleaned after it is spent from the motor means.

The fluid motor means may be of any convenient form, but preferably comprises a turbine, being either an impulse turbine fixed to the rotor means, having blade means surrounding the rotation axis and stationary feed nozzle means for directing one or more streams of fluid at the blade means, or a reaction turbine having a plurality of jet reaction nozzles carried by the rotor means.

Notwithstanding the form of the drive means, the inlet means may comprise collection means operable to receive contaminated liquid from the housing inlet means and defining an inlet region about the rotation axis, and transfer passage means communicating between the inlet

region and the contaminant separation and containment zone.

The collection means may, if fluid motor means is employed, be arranged to receive spent liquid from the fluid motor means.

The collection means may comprise a divider wall also extending about and along the rotation axis disposed radially between the rotation axis and the outlet passage means, the divider wall having a collection face least in part facing towards the rotation axis and bounding said inlet region.

The inlet means may be operable to direct a stream of the contaminated liquid onto the rotating collection face to form a film or layer of liquid thereon and spread centrifugally by said rotation towards the transfer passage means.

The divider wall may extend at substantially uniform distance from the rotation axis, defining a substantially cylindrical collection face, or may increase in distance from the rotation axis as a function of axial distance from the outlet passage means, that is, be tapered. The transfer passage means of such tapered divider wall may be confined or concentrated at a position of maximum distance, and may comprise an axial end of the divider wall.

Irrespective of the shape of the divider wall, the transfer passage means may comprise an array of through apertures in the divider wall. Preferably, the density and/or dimensions of said apertures increases with increasing axial distance from the outlet passage means.

Alternatively, when the fluid motor means is a reaction turbine, the transfer passage means may comprise jet reaction nozzles of the reaction turbine.

The divider wall may be displaced from the rotation axis so that it lies substantially adjacent the outlet passage means.

Advantageously, the inlet means is mounted with respect to the housing by bearing means and at least the radially outer wall of the separation and containment vessel, and the contaminant separation and containment zone defined thereby, comprises a module adapted for releasable attachment to the inlet means.

The separation and containment vessel may have associated therewith, and nested radially inwardly of the contaminant separation and containment zone, at least one further separation and containment vessel, having an impervious radially outer side wall, an annular contaminant separation and containment zone bounded radially inwardly of said side wall by outlet passage means and inlet means arranged to convey liquid to the zone at a lesser rate than it is capable of draining therefrom, each said further vessel being disposed such that the outlet passage means of each surrounded vessel permits liquid to be conveyed radially by centrifugal forces to the next surrounding vessel.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which

Figure 1 is a sectional elevation through a first embodiment of centrifugal separation apparatus in accordance with the invention, including impulse turbine drive means as the source of contaminated liquid and inlet means in the form of an axially extending, perforated divider wall,

Figure 2 is a sectional elevation through a second embodiment of centrifugal separation apparatus in accordance with the invention, illustrating a divider wall of tapered form,

Figure 3 is a sectional elevation through a third embodiment of centrifugal separation apparatus in accordance with the invention illustrating variants of components,

Figure 4 is a sectional elevation through a part of a fourth embodiment of centrifugal separation apparatus in accordance with the invention illustrating a variant of impulse turbine drive means,

Figure 5 is a sectional elevation through a part of a fifth embodiment of centrifugal separation apparatus in accordance with the invention illustrating a further variant of impulse turbine drive means in which the spent liquid is not the source of the contaminated liquid to be cleaned,

Figure 6 is a sectional elevation through a sixth embodiment of centrifugal separation apparatus in accordance with the invention illustrating a further variant of inlet means,

Figure 7 is a sectional elevation through a seventh embodiment of centrifugal separation

apparatus in accordance with the invention including reaction turbine drive means.

Figure 8 is a sectional elevation through an eighth embodiment of centrifugal separation apparatus in accordance with the invention illustrating a further variant of reaction turbine drive means, the spent liquid of which is the source of contaminated liquid to be cleaned,

Figure 9 is a sectional elevation through a ninth embodiment of centrifugal separation apparatus in accordance with the invention illustrating a further variant of reaction turbine drive means in which the spent liquid is not the source of the contaminated liquid to be cleaned,

Figure 10 is a sectional elevation through a tenth embodiment of centrifugal separation apparatus in accordance with the invention, illustrating further variants to the rotor means,

Figure 11 is a schematic representation in sectional elevation of part of an eleventh embodiment of centrifugal separator in accordance with the invention, illustrating the inclusion of further vessels within the walled contaminant separation and containment vessel, and

Figure 12 is a schematic representation in sectional elevation of part of a twelfth embodiment of centrifugal separator showing modification of the multi-vessel arrangement of Figure 11.

Referring to Figure 1, a first embodiment of centrifugal separator 110 comprises a housing 112 defined by a base 114, adapted to be affixed to the engine block of an internal combustion engine (not shown), and a removable cover 116. The base includes inlet duct means 118, by which contaminated liquid is supplied at elevated pressure, and outlet duct means 120 for drainage of liquid from the housing to the engine sump.

A spindle 122, having longitudinal axis 124, is supported at one end thereof 122_1 by the base and extends through the housing and engages at its other end 122_2 with the cover 116.

Mounted on the spindle for rotation about the axis 124 within the housing is rotor means 130, comprising a walled containment separation and containment vessel 132 (hereafter referred as "the vessel") which has an impervious, radially outer side wall 134 extending about, and lengthways of, rotation axis 124 between end walls 136 and 138. Radially inwardly from the side wall 134 is an annular contaminant separation and containment zone 140 (hereafter referred to as "the zone"), the radially inner boundary of the zone, as denoted by the broken

line 141, being defined by outlet passage means 142 in the end wall 138 which leads externally of the vessel within the housing. The outlet passage means 142 may comprise one or more apertures, in the form of circumferentially extending slots, in the end wall or may comprise an annular gap representing a radial space between the end wall 138 and inlet means, indicated generally at 150 and described hereinafter, which is arranged to convey contaminated liquid from radially inwardly thereof to the zone 140.

The rotor means is mounted with respect to the spindle 122 by way of a tubular axle 144 which surrounds the spindle and is mounted by axially spaced needle roller bearings 146_1, 146_2, or equivalent low friction bearings, and held captive by a nut 148.

The inlet means 150 comprises a divider wall 152, also extending about and lengthways of the rotation axis 124, disposed radially between the tubular axle 144 and the zone 140, preferably adjacent the latter and possibly defining one boundary of the outlet passage means 142. The divider wall 152 is mounted in fixed relationship to the tubular axle, at one of its axial extremities by radially extending wall 154 and at the other, optionally, by bracing spars 156, but nevertheless apertured for drainage and possibly absent altogether. The wall 152 has an inlet or collection face 158 facing towards the rotation axis and defining between the face and the tube axle 146 an inlet region 160.

Transfer passage means, indicated generally at 162, communicates between the collection face 158 and the zone 140, taking the form of a plurality of through-apertures 164 in the divider wall. Preferably the apertures are concentrated in density towards the end of the divider wall axially remote from the outlet passage means but at any axial position are uniformly distributed circumferentially.

With the tubular axle 144, the divider wall 152 and the end wall 154, form the main structural element of the rotor means by which it is carried on the spindle and with respect to the housing.

The radially outer wall 134 and end walls 136 and 138, which define the contaminant separation and containment zone 140 and outlet passage means 142, are formed as a discrete separation and containment module 132_1 arranged to be removably mounted with respect to the inlet means 150 by way of engagement between the radially inner edge 136_1 of the end wall 136 on a radially overhanging lip 154_1 of the end wall 154. The module 132_1 is

conveniently moulded of plastics material and may include any conventional strengthening features, such as circumferential ribs to enable it to withstand the stresses of high speed rotation and the forces exerted by the liquid and deposited contaminants in the zone 140.

The inlet means 150 also collects contaminated liquid to be cleaned on the collection face, which it does by way of rotor drive means, indicated generally at 170. The drive means comprises a fluid motor in the form of an impulse turbine 172. The impulse turbine 172 comprises a plurality of turbine blades 174, each of which may have a concave, bucket-like form also known as a Pelton wheel, arrayed surrounding the rotation axis 124 and fixed with respect to the rotor means. The blades may individually, or as an array sub-assembly, be secured to an end region of the tube axle 144 or formed integrally therewith as shown.

The turbine 172 also comprises a plurality of liquid jet nozzles 176, each of which extends from the base 114 and is coupled to the high pressure supply duct 118 to direct a jet 178 of the contaminated liquid at a particular bucket position, substantially tangentially with respect to the rotation axis but also inclined longitudinally with respect thereto such that liquid deflected by, or otherwise splashed after, impact with a blade is caused to enter inlet region 160 and impinge upon the collection face 158 of the inlet means, as illustrated by broken boundary lines 178'.

Thus, in operation contaminated liquid supplied to the arrangement initially uses its energy to effect high speed rotation of the rotor means including the collection face 158, so that spent turbine liquid which impinges upon the collection face is spread into a covering film by the centrifugal forces of rotation. Liquid of the film passes through the apertures 162 of the passage means and is thrown towards the radially outer wall 134.

The turbine means is arranged in conjunction with the outlet passage means to ensure that contaminated liquid is supplied to the collection face 158 at a rate less than that at which it can drain through the outlet passage means 142 , so that a layer of liquid and contaminants is held against the outer wall 134 to a thickness no greater than the contaminant separation and containment zone 140 defined by the radial position of the outlet passage means and the vessel is otherwise substantially empty. Insofar as such zone is at maximum distance from the rotation axis, centrifugal forces are at maximum and any heavier contaminants are separated from the liquid to agglomerate into a layer against the wall with the liquid overlying it. Separation can thus continue until the contaminant deposits fill the zone and further

contaminants are washed directly through the outlet passage means.

Thereafter, separation and contaminant module 132_1 can readily be separated from the inlet means and cleaned or discarded, being replaced with a cleaned or new module. As indicated above the module may be manufactured from plastics material which enables it to be manufactured cheaply as a "consumable" which can readily be destroyed with the contaminants collected therein and which reduces the inertia of the rotor means in operation.

In keeping with reducing the inertia of the rotor means, it is an important feature of the invention that in operation the vessel of the rotor means is not filled with the liquid, unlike the normal operating conditions of such cleaning arrangements, and rapidly brought up to operating speed by direct turbine drive and without awaiting for the rotor to fill with liquid. Also, because in this embodiment the tubular axle is not filled with liquid at elevated pressure, the bearings 146_1 and 146_2 may be chosen for low energy loss without regard to liquid containment.

Many of the individual components may take alternative form, and in general may be varied independently of each other.

Referring now to Figure 2, this shows in similar sectional elevation a second embodiment of centrifugal separator 210 which illustrates one such variant. Identical components retain the same reference numbers and corresponding, but different components have reference numbers with a leading "2".

The separator 210 comprises the aforementioned housing 112 defined by base 114 cover 116 and spindle 122. Housed rotor means 230 is substantially the same as rotor means 130 except in respect of inlet means 250 which includes a divider wall 252 of slightly conical form, increasing in radius with distance from the end 252_1 at which liquid is introduced towards end 252_2 adjacent wall 254 and defining a similarly shaped inlet region 260. Also, instead of aperture means in the form of an array of through-apertures scattered radially and axially thereof, aperture means 262 comprises circumferentially extending slots 264 disposed only towards the end of maximum radius.

Impulse turbine drive means 172 is as described above, and contaminated liquid is directed by nozzles 176 towards impulse turbine blades 174 to effect rotation of the rotor means and

spent liquid is directed on to collection face 258 of the divider wall. As described above, the centrifugal forces of rotation spread the liquid as a film over the collection face and here the variation in radius encourages the liquid to migrate to the upper end 252_2, whereupon it passes through slots 264 and is flung toward the outer wall 134 of the module 132_1. Insofar as the liquid enters the contaminant separation and containment zone 140 at the end remote from the outlet passage means 142, it is caused to dwell in the zone for the maximum possible separation time.

Other components and structural relationships may be employed without departing from the spirit of the invention and Figure 3 shows in sectional elevation a third embodiment of centrifugal separator 310 which illustrates possible variants. Components identical to those of the first and second embodiments have the same reference numbers whilst differing components have reference numbers with a leading "3".

The separator 310 comprises the aforementioned housing 112 defined by base 114 cover means 116 and spindle 122, the latter defining rotation axis 124. Housed rotor means 330 is mounted on the spindle 122 by tubular axle 344.

The rotor means comprises a walled vessel 332 bounded externally by impervious outer side wall 334 extending about, and lengthways of, the rotation axis between end walls 336 and 338. The end wall 336 is clamped with respect to the end of the axle means by nut 148 which also locks the tubular axle onto the spindle.

The end wall 338 contains therein outlet passage means 342 displaced radially inwardly of the side wall 334 to define between the passage means as said side wall a contaminant separation and containment zone 340 as indicated by broken lines 341. Displaced radially inwardly of the outlet passage means and extending substantially parallel to the outer wall 334 is an optional inner wall 335 which defines a physically bounded separation and collection chamber 340_1 of separated contaminants little greater than the 340.

Inlet means 350 includes a divider wall 352 which surrounds and extends axially of, the rotation axis 124, and the tubular axle 344, being disposed with respect to the tubular axle by spars 353. The divider wall is tapered, increasing in radius as a function of distance from the end 352_1 adjacent base 114, and otherwise open at its upper end 352_2 which is spaced axially from the end wall 336 so as to provide a substantially unobstructed annular transfer passage

means 362 between collection face 358 of the divider wall and the contaminant separation and containment zone 340 at the outer wall 334.

As a matter of structural convenience and to impart operational strength thereto, the upper end of the inner chamber wall 335 is shaped to locate over the upper end 352_2 of the divider wall 352.

Furthermore, and illustrative of a further variant, drive means 370 takes the form of an impulse turbine 372 having stationary liquid jet nozzles 376 and generally flat blades 374 fixed with respect to the tubular axle between its ends so that substantially all of the spent turbine drive liquid impinges upon collection face 358 of the divider wall.

Operation is substantially as described above, with contaminated liquid supplied at elevated pressure to supply duct 118 from where it is directed by nozzles 376 towards turbine blades 374 to effect rotation; spent liquid, deflected by the turbine blades to impinge upon the conical collection face 358, is held there by centrifugal forces of rotation and migrates towards the upper end 352_2 of the divider wall before being flung by these centrifugal forces through the annular gap 362 towards outer wall 334, whereupon it further spreads and flows generally towards outlet passage 342, heavier contaminants being separated from the liquid and caused to agglomerate against, and bond to, the wall or any previously separated contaminants.

When the zone 340 is filled by the separated contaminants, the separation and containment module 332_1 is readily removed from the rotor means by releasing nut 148 and replaced with an empty one. The optional inner wall 335 effectively prevents any inadvertent dislodging of the deposited contaminants from the outer side wall 334, and as described above, the separation and containment module 332_1 may be formed as a discardable plastics moulding. In all of the above described embodiments the drive means for the rotor means is an impulse turbine having blades fixed to a tubular axle surrounding a stationary spindle and supplied with liquid by stationary feed nozzles.

Considering further structural variants, such impulse turbine blades (whether flat or bucket-like) may be mounted elsewhere, provided the spent liquid impinges directly or indirectly upon the collection face of the divider wall. Referring to Figure 4, in which is illustrated in sectional elevation a part of a fourth embodiment of separation apparatus 410, this is the same as the third embodiment except for drive means 470 in the form of an array of bucket-like turbine

blades 474 mounted directly on collection face 458 of the divider wall.

Referring now to Figure 5, this shows in sectional elevation part of a fifth embodiment of centrifugal separation arrangement 510 that is generally similar to the separation arrangement 210 in respect of the inlet means and impulse turbine, but wherein the liquid to be cleaned is directed totally or in part directly upon the collection face 258 of divider wall 252 by way of feed nozzle means 576_1 and the turbine operated in isolation therefrom or in conjunction therewith, being fed by nozzle means 576_2, to effect rotation of the rotor means at an appropriate high rate. It also illustrates the possibility of supplying contaminated liquid to feed nozzle 576_1 completely independently from the supply to nozzle means 567_2, although of course they may have a common supply as described above. It may be advantageous to have such discrete supples when for instance, the liquid to be cleaned is heavily contaminated and unsuitable for passing through a relatively small nozzle jet for driving the turbine and/or is available at a low or variable pressure or intermittently, such as in the circumstances discussed in the aforementioned US 5906733.

Referring to Figure 6, a sixth embodiment of centrifugal separator 610 is shown in sectional elevation and once more, previously described parts have the same reference numbers whilst parts unique to the embodiment have reference numbers with a leading "6". The housing 112, with base 114 and cover 116, is as described above. Spindle 622 corresponds to the above-described spindle 122 except that it has the supply duct 118 extending axially therealong as inlet passage 618 to cross drillings 619.

Rotor means 630 mounted on the spindle comprises a separation and containment vessel 632 having a side wall 634, extending about and along the rotation axis 124, and radially directed end walls 636 and 638. The side wall defines one radial limit of contaminant separation and containment zone 640, the other radial limit being defined by outlet passage means 642 in the end wall 638. Bearings 646_1 and 646_2 carried by said end walls mount the vessel rotatably on the spindle without the need for a separate, tubular axle.

Inlet means, by which contaminated liquid is fed to the zone 640, is indicated generally at 650, comprising the spindle passage 618 and cross drilling 619 which deliver the liquid directly into the vessel and directed towards the zone 640 and without the intermediary of a divider wall, although for comparison with the above described embodiments, the spindle surrounding the passage 618 may be considered to form the divider wall and the cross drilling 619 to form the

transfer passage means.

Drive means, indicated generally at 670, comprises impulse turbine 672 of blades 674 and tangentially directed feed nozzle 676.

As with the fifth embodiment, the liquid to be cleaned within the vessel is separate from that of the drive means, although from the same supply duct 118, and permits the flow of each to be optimised. The supplies could, of course, be separate as illustrated by the sixth embodiment.

It will be appreciated that insofar as the rotor means is operated with relatively little liquid therein, it may be spun at high speed using the contaminated liquid pressure by drive means other than an impulse turbine, such as the more traditional reaction turbine. Referring to Figure 7, a seventh embodiment of centrifugal separator 710 is shown in sectional elevation and once more, previously described parts have the same reference numbers whilst parts unique to the embodiment have reference numbers with a leading "7". The housing 112, with base 114 and cover 116, as described above. Spindle 722 corresponds to the above-described spindle 122 except that it has the supply duct 118 extending therealong axially as inlet passage 718 to cross drillings 719.

Rotor means 730 is mounted on the spindle by way of bearing bushes 746_1 and 746_2 disposed at opposite ends of tubular axle 744. The tubular axle is surrounded by a walled separation and containment vessel 732 defined by an outer side wall 734 spaced therefrom by end walls 736 and 738, the wall 738 including outlet passage means 742 positioned radially to define contaminant separation and containment zone 740. The tubular axle 744 provides both inlet means, indicated generally at 750, and drive means, indicated generally at 770.

In respect of the inlet means, the tubular axle comprises an effective divider wall 752 and defines with the spindle an annular inlet region 760 fed by way of the passage 718. The tubular axle/divider wall is also provided with transfer aperture means 762 in the form of a plurality of apertures 766. In respect of the drive means 770, the apertures 766 comprise tangentially directed jet reaction nozzles, which eject contaminated liquid from the inlet chamber and by reaction thereto cause the rotor means to spin about the spindle.

The reaction nozzles thus spray ejected liquid, spent of most but not all of its energy, in a

direction away from the rotation axis of the rotor means, which liquid impinges upon the vessel outer wall 734 and spreads thereon as a film overlying the wall, and subsequently overlying contaminants separated from the liquid, within the zone 740 as described above. Insofar as the divider wall is spaced from the boundary of the zone 740 and the outlet passage means defining the zone, and there exists a risk of deposited contaminants falling from a filled vessel when it is not rotating, it may be desirable to define a floor to the vessel radially inwardly of the outlet passage means, as shown by broken lines 780 or define the outlet passage means at an upwardly facing end, that is, in end wall 736 rather than end wall 738.

It will be appreciated that although the inlet region 760 within the axle tube is filled with liquid and the effect thereof, in terms of the need to effect substantial sealing of the axle chamber on the spindle by the bearing bushes (or otherwise) and the lower efficiency of reaction jet turbine, is an improvement over existing reaction driven separation arrangements because the liquid is confined to smaller radially inner and outer proportions of the rotor means.

Referring now to Figure 8 this shows a sectional elevation an eighth embodiment of centrifugal separation arrangement in accordance with the present invention, and a variant of the seventh embodiment, at 810. Within housing 112, fixed spindle 822 has a supply duct 818 for incoming contaminated liquid at elevated pressure and has mounted rotatably thereon a walled separation and containment vessel 832 defined by radially outer wall 834 and end walls 836 and 838, in the latter of which is formed outlet passage means 842 that defines a contaminant separation and containment zone 840 adjacent the wall 834. The radially inner boundary of the vessel is the spindle, that is, there is no separate tubular axle, although there could be if desired. As in the previous embodiment, the arrangement combines inlet means, which is here indicated generally at 850, and drive means, indicated generally at 870. The vessel 832 is divided internally at least in part by a radially extending divider wall 852 which forms annular inlet chamber 860 surrounding the spindle and fed by way of the duct 818 and cross drilling 819. In respect of inlet means, the divider wall 852 is also provided with transfer aperture means 862 in the form of a plurality of apertures 866 by way of which contaminated liquid is directed to the zone 840. In respect of the drive means 870, the apertures 866 comprise tangentially directed jet reaction nozzles, which eject contaminated liquid from the inlet chamber towards the zone 840, and by reaction thereto cause the rotor means to spin about the spindle, enabling separation of contaminants to be effected in the zone 840 at the radially outermost part of the vessel.

The inlet chamber 860 thus comprises a drive chamber and may be of small volume sufficient to function as a reaction turbine to rotate the other vessel 832 at high speed and preferably is shaped to encourage contaminated liquid passing therethrough to do so without separation of contaminants. The major part of the vessel 832 which receives the ejected and spent liquid directed towards its outer wall, is not filled with the liquid but in operation contains only a relatively small amount as dictated by the contaminant separation and containment zone.

Referring now to Figure 9, this shows in sectional elevation a ninth embodiment of centrifugal separator 910.The arrangement is somewhat similar to the eighth embodiment in having rotor means 930 in the form of a pair of axially disposed, rotationally coupled vessels defined about spindle 922, one of which, 932, defines contaminant separation and containment zone 940 and the other of which comprises drive means 970.

Inlet means to the vessel 932 comprises spindle duct 918 and cross drilling 919_1 which preferably contains some form of diffusing means (not shown) to spay the liquid towards the outer wall 934, where it forms a layer only to the thickness of the contaminant separation and containment zone 940 defined by outlet passage means 942.

Drive means 970 comprises a reaction jet turbine 972 formed by vessel 973, closed except in respect of liquid inlet from the spindle by way of cross drilling 919_2 and liquid outlet by way of reaction jet nozzles 966 in the vessel wall. The vessel 973 has small volume, sufficient to function as a reaction turbine to rotate the other vessel 932 at high speed and preferably is shaped to encourage contaminated liquid passing therethrough to do so without separation of contaminants.

Insofar as the contaminated liquid supplied to the contaminant separation and containment zone is separate from that employed to rotate the rotor means, the relative flow rates may be chosen having regard to maximising the rotation rate whilst providing a relatively long dwell time in the contaminant separation and containment zone.

In accordance with the spirit of the present invention the above described reaction turbine drive chamber 860 and vessel 973 each has a small, but nevertheless significant volume. It will be appreciated that if desired, such a reaction drive may be defined without filtering such a chamber per se, that is, with minimal volume, by means of discretely feeding the reaction jet nozzles by individual ducts in the manner set out in US 5906733.

It will be appreciated that although all of the above described embodiments have shown the outlet passage means defined at the lower wall of the rotor vessel in relation to a vertical rotation axis, this is not a functional necessity. The outlet passage means may be defined in the upper end wall or radially outer wall or any combination thereof, provided that the contaminant separation and containment zone is properly defined and liquid exiting the vessel by way of the outlet passage means does not interfere with the rotation. In this context the impervious nature of the radially outer wall should be taken to be exclusive of such outlet passage means. Likewise, depending upon the drive means, it may be possible to operate with the rotation axis at any non-vertical orientation.

Furthermore, although all of the above embodiments have been described with a stationary spindle, such may be rotatably mounted with respect to the housing for rotation about the axis 124, a discrete tubular axle 124 being then unnecessary. Furthermore, spindle means may comprise a pair of axially spaced stub axles at opposite ends of the housing and carried by, or extending into, the rotor means.

Referring now to Figure 10, this shows in sectional elevation a tenth embodiment of centrifugal separation arrangement 1010 in accordance with the present invention. Housing 1012 is defined by base 1014 and removable cover 1016. The base includes inlet duct means 1018 and recess 1019 for supporting one end 1022_1 of spindle 1022 for rotation with respect thereto by way of bearing means 1046_1. The supply duct opens into the recess 1019 and the spindle contains a duct 1018_1 extending therealong from the end and in communication with the supply duct by way of the recess. A further spindle 1022_2 is mounted by way of bearing means 1046_2 to the cover 1016 for rotation relative to the common longitudinal axis 1024. The spindles form part of rotor means indicated generally at 1030. The spindle duct 1018_1 connects to a pair of axially spaced cross drillings 1019_1 and 1019_2. Mounted on the spindle 1022_1 in alignment with the cross drilling 1019_2 is a vessel 1032 having an impervious outer wall 1034 extending about and along the axis 1024 and displaced therefrom by end wall 1036 which is fixed permanently, or releasably threaded, to the spindle 1022_1. At the other end of the outer wall 1034, end wall 1038 is connected to the spindle 1022_2 but apertured at a predetermined distance from the rotation axis to define outlet passage means 1042, and thereby contaminant separation and containment zone 1040. The rotor means also comprises drive means 1070 in the form of reaction turbine means 1072, comprising a plurality of stand pipes 1073 each aligned with the cross drilling 1019_1 and terminating adjacent the cover 1016 in a jet reaction nozzle 1076.

Operation is essentially as described above in relation to the seventh, eighth and ninth embodiments driven by reaction turbines but with minimal liquid contained in the rotor means for minimum inertia. Also, this embodiment illustrates the outlet passage means at the upper end of the housing. The spindle ends 1022_1 and 1022_2 may of course, comprise end regions of a single spindle 1022 as shown by the broken joining lines 1022_3.

It will be appreciated that outlet passage means may be disposed at such "upper end" of the separation and containment vessel in any of the above described embodiments, or indeed at both ends.

All of the embodiments described above have employed drive means in the form of impulse or reaction turbines which are powered by the contaminated liquid either separately from or as a precursor to it undergoing contaminant separation, this being one of the most convenient power sources available to such arrangement within a functioning internal combustion engine. It will be appreciated that there are numerous other forms or turbines or non-turbine motors driven by liquid or gaseous fluids that could be adapted for an arrangement in accordance with the present invention. Also, insofar as the arrangement is capable of being designed to effect centrifugal cleaning of contaminated liquid separately from driving the rotor means, the drive means does not need to be powered by the contaminated liquid, nor indeed liquid or any other fluid at all. For example, the rotor means could be driven by electric motor means or mechanical linkage to an engine whose lubricant is being cleaned and achieve high rotation speeds by way of gearing.

Other structural variations are possible. For instance, the inlet means may be displaced axially from the separation and containment vessel, particularly where the inlet means directs incoming liquid axially to a transfer passage and the transfer passage shares the same axial position at at least one end of the vessel.

Although for optimum conditions of minimal inertia and separation radius, the separation and containment vessel comprises little more than a radially impervious wall at maximum distance, it will be appreciated that if it anticipated that only a minor proportion of the particulate contaminants are of such low density as to require these conditions, then it may be feasible to include coaxially within the vessel, radially between the outer wall and the rotation axis, one or more nested further vessels having substantially the same structure, in terms of outlet passage means defining a contaminant separation and containment zone adjacent an

impervious radially outer wall, but each providing by such outlet passage means the liquid for the next outer vessel.

Referring, now to Figure 11, this shows a schematic representation in sectional elevation of part of a an eleventh embodiment of centrifugal separation apparatus 1110 in accordance with the invention, and based upon the embodiment 210 to which reference is made for the parts not shown. The Figure does show a portion of (static) cover 116 enclosing rotor means 1130.

The rotor means comprises inlet means 1150, in the form of tapered divider wall 1152 having radially inwardly facing collector face 1158, and, adjacent the end thereof, transfer passage means 1162, as well as separation and containment vessel 1132 mounted thereto by radially extending spacer spars (not shown) for rotation therewith. The vessel 1132 comprises axially extending, impervious wall 1134 and at each end thereof vestigial end walls 1136 and 1138 which are directed both axially and radially to collect liquid approaching in a radial direction and to define the radial limit of a contaminant separation and containment zone 1140, that is, the radial limit of outlet passage means 1142.

Also mounted on, and coaxially with, the inlet means are a plurality, here two, of further separation and containment vessels 1132_A and 1132_B radially inwardly of the vessel 1132. The further vessels are substantially identical to the vessel 1132 in having vestigial end walls 1136_A , 1138_A, 1136_B and 1138_B that define outlet passage means and thereby contaminant separation and containment zones 1140_A and 1140_B respectively, but also are progressively shorter in axial length towards the inlet means so that liquid exiting the outlet passage means of each is flung radially outwardly towards, and collected by, the next vessel. As can be seen, the transfer passage 1162 of the inlet means is aligned substantially with the mid points of the surrounding vessels.

Operation will be seen to correspond to that described above with each vessel or further vessel containing a relatively thin, annular skin of liquid and contaminants separated therefrom having densities appropriate to the distance from the axis, progressively cleaner liquid with lower density contaminants eventually arriving at the outermost vessel 1132. Insofar as each of the further vessels may be made of low density, plastics materials, the weight, and thus inertia of the multi-vessel rotor means, can still be significantly less than a single vessel completely filled with liquid.

There are may structural variations possible in terms of the size and dispositions of such further vessels and Figure 12 illustrates some of these in a composite construction of such a schematic part view of separation apparatus 1210. Referring to the Figure, the outer cover 116 and inlet means 1250 is substantially as described above. Rotor means comprises an outermost separation and containment vessel 1232 and coaxially therein, a plurality of spaced apart further vessels 1232_i, where i is here A to E.

Considering the further vessels 1232_E and 1232_D that make up section I, these (and possibly all vessels) are of uniform length, but the outlet passage means 1242_E and 1242_D is defined at one end only of each, which end alternates for successive vessels so that the liquid follows a meandering path along the full length of each.

Considering the further vessels 1232_D, 1232_C and 1232_B that make up section II, these (and possibly all vessels) are progressively shorter with distance from the rotation axis as well as being disposed axially to effect a meandering path for the liquid. Such arrangement has the functional effect of minimising the inertia of the rotor means and permitting a more tapered, streamlined shape for the cover.

Consider the further vessel 1232_A and vessel 1232 that make up section III, these (and possibly all vessels) have at the end where liquid is received from the outlet passage means 1242_A of the preceding further vessel an end wall 1236 which is shaped as a splitter to divert only a proportion of the liquid into the vessel.

It will be appreciated that where one or more further vessels are employed nested within the outer vessel, the outer side walls need not extend parallel to that of the outer vessel. Likewise, although each outlet passage means and further outlet passage means has been shown in an end wall of each vessel or further vessel, it may be provided in an appropriately shaped side wall.

It is a fundamental feature of all of the embodiments described above that the separation and containment vessel defined by, and radially inwardly of, the impervious radially outer side wall, is not filled with liquid and has a relatively thin contaminant separation and containment zone adjacent the wall and as such provides a structure wherein the radial position of the outer wall is not a determining factor in the bulk of the liquid contained and rotated and is free of centrifugal pressure gradient flow behaviours of such liquid.

These operating principles thus enable completely novel constructions of rotor means for this type of engine lubricant cleaning arrangement which is readily substituted within the "real estate" made available on such an engine for cleaning by the traditional arrangements.

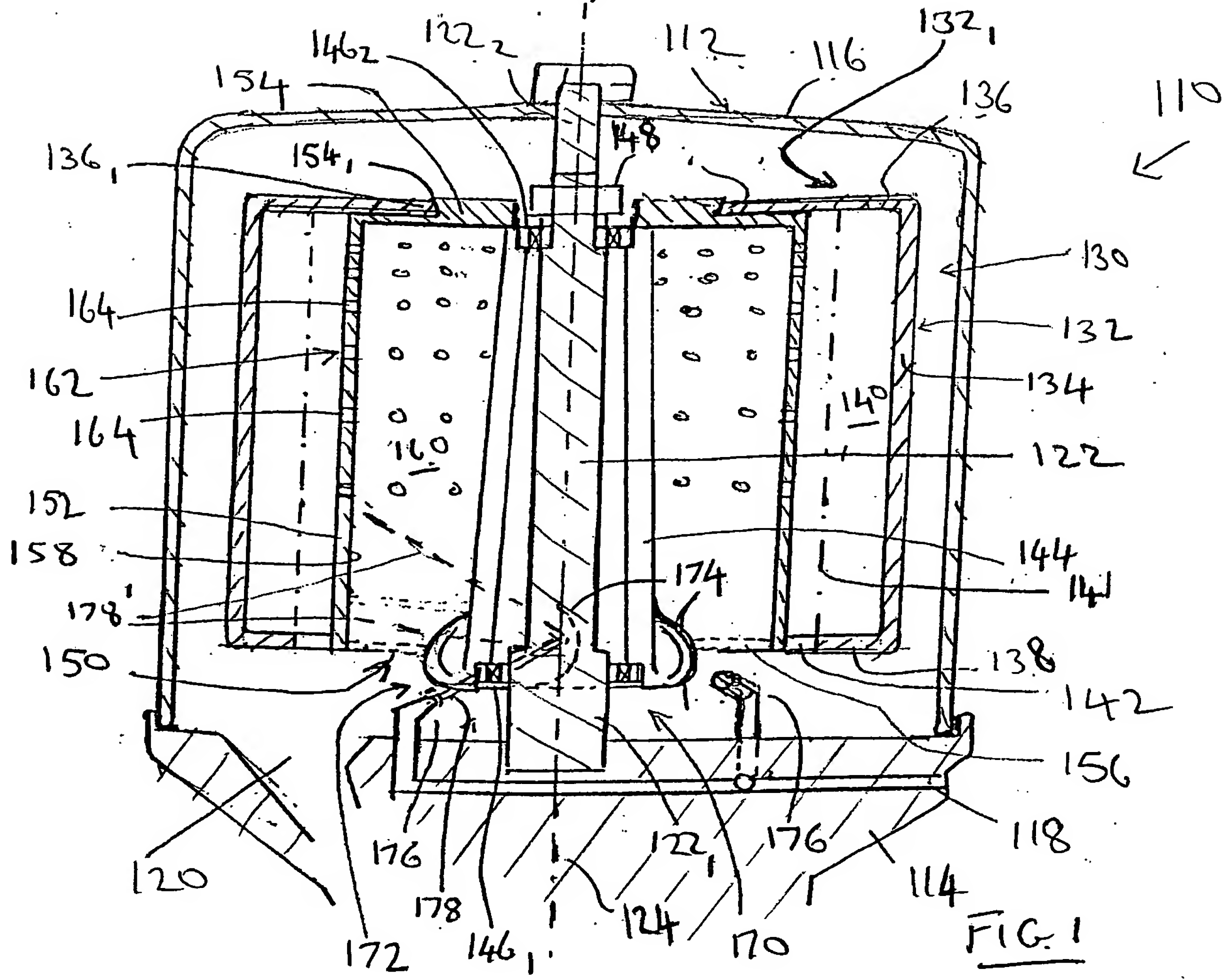

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FIG. 1

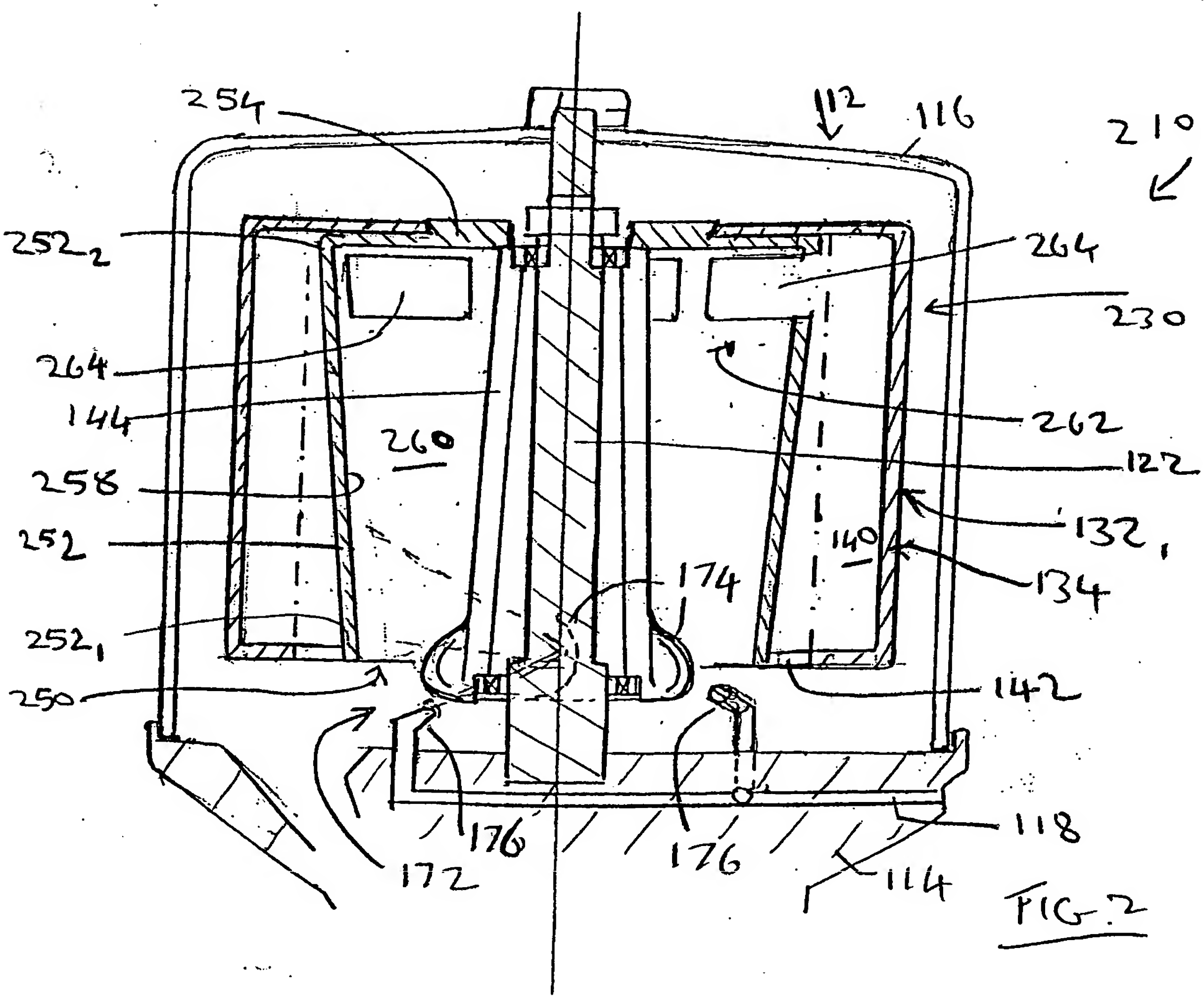

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FIG. 2

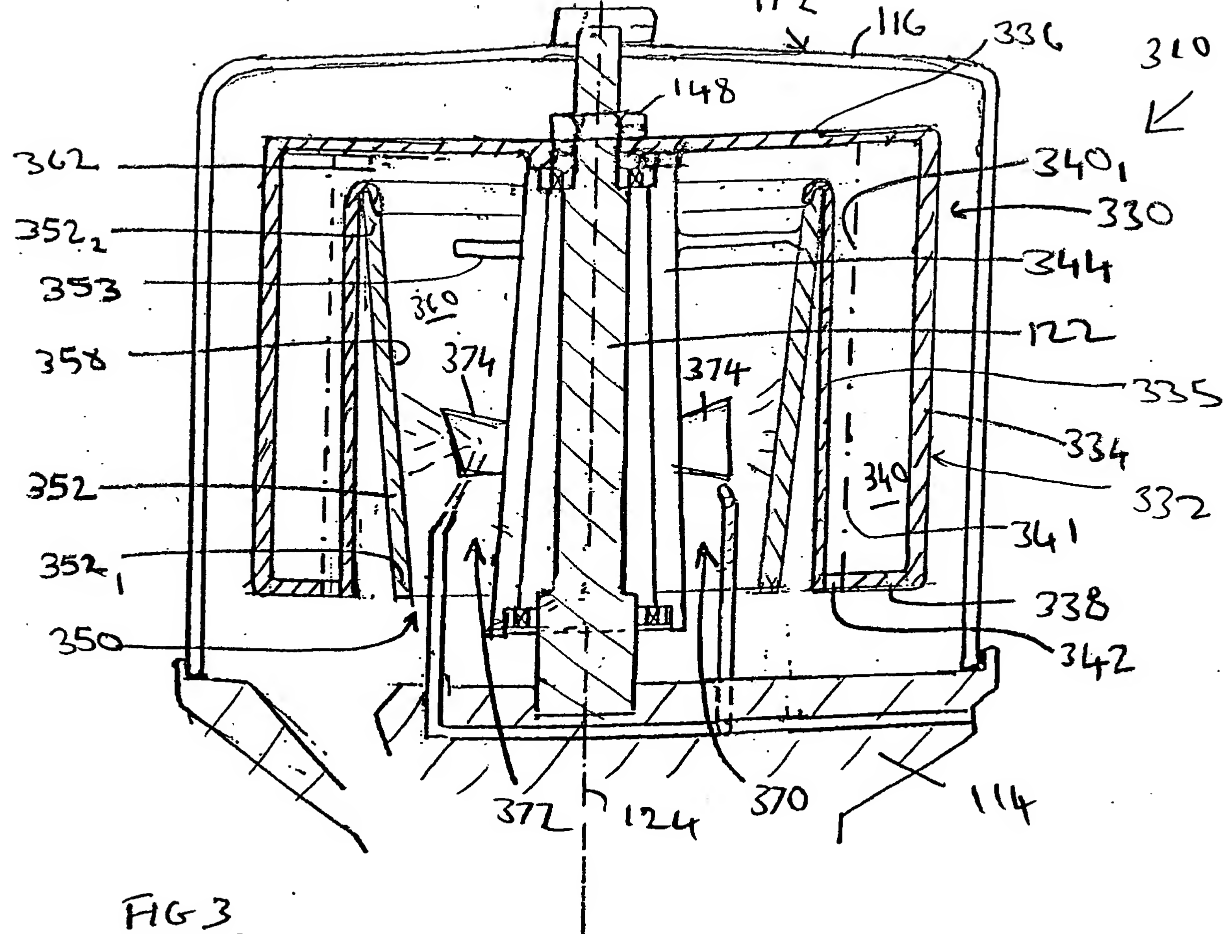

FIG 3

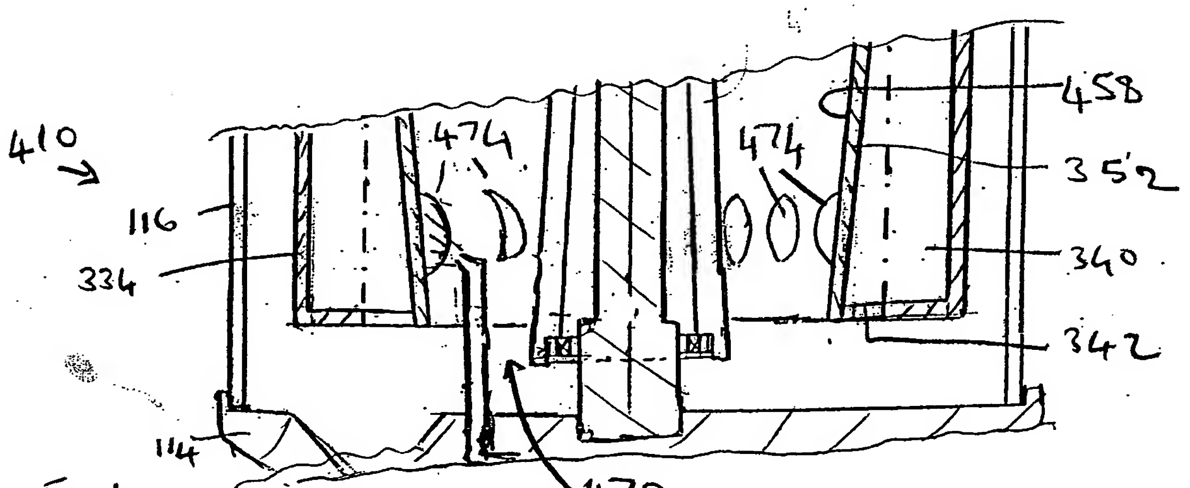

FIG 4

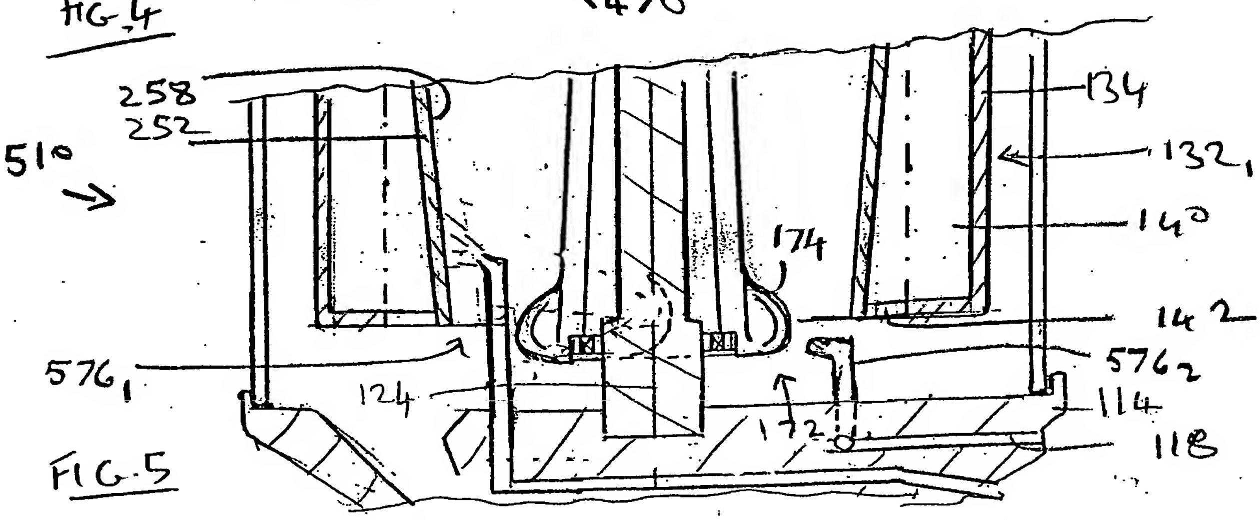

FIG 5

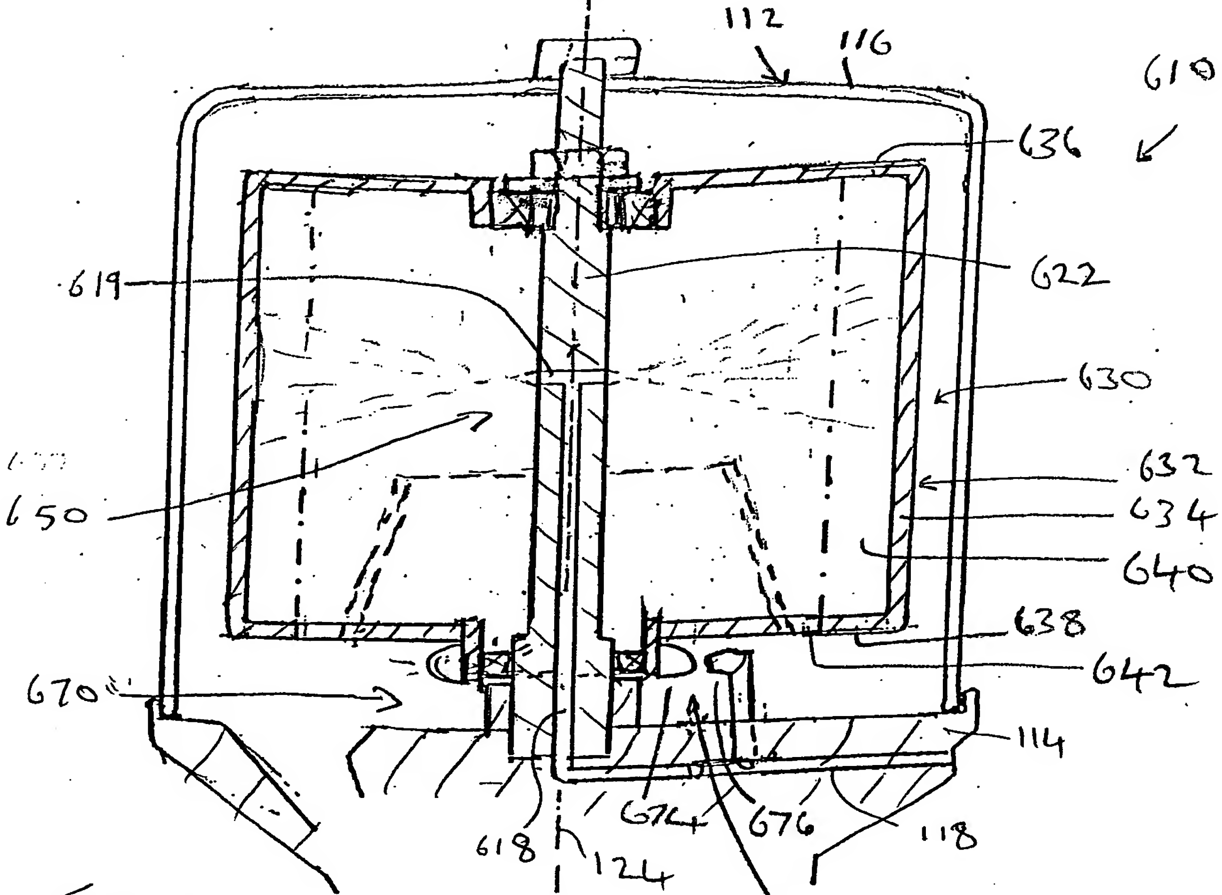
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FIG 6

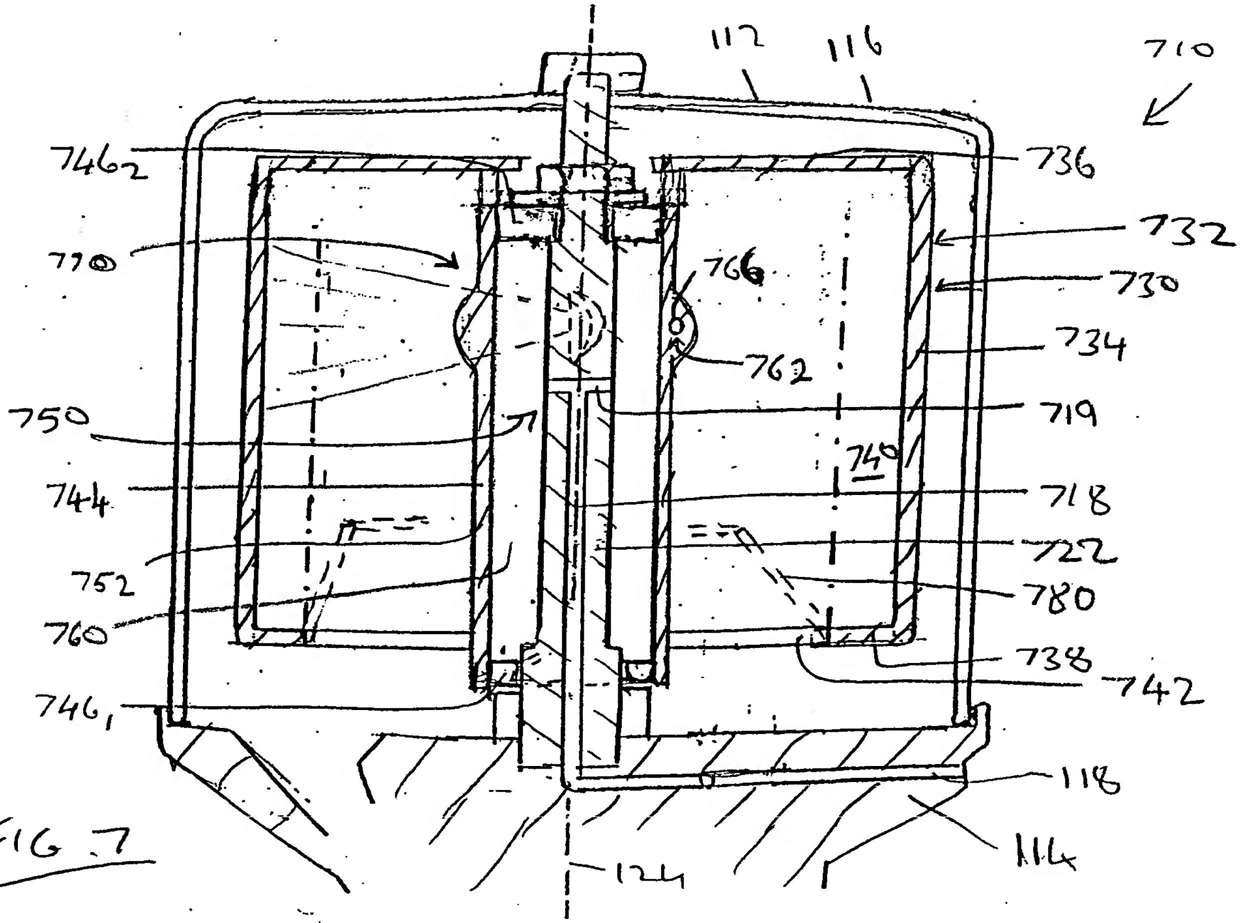
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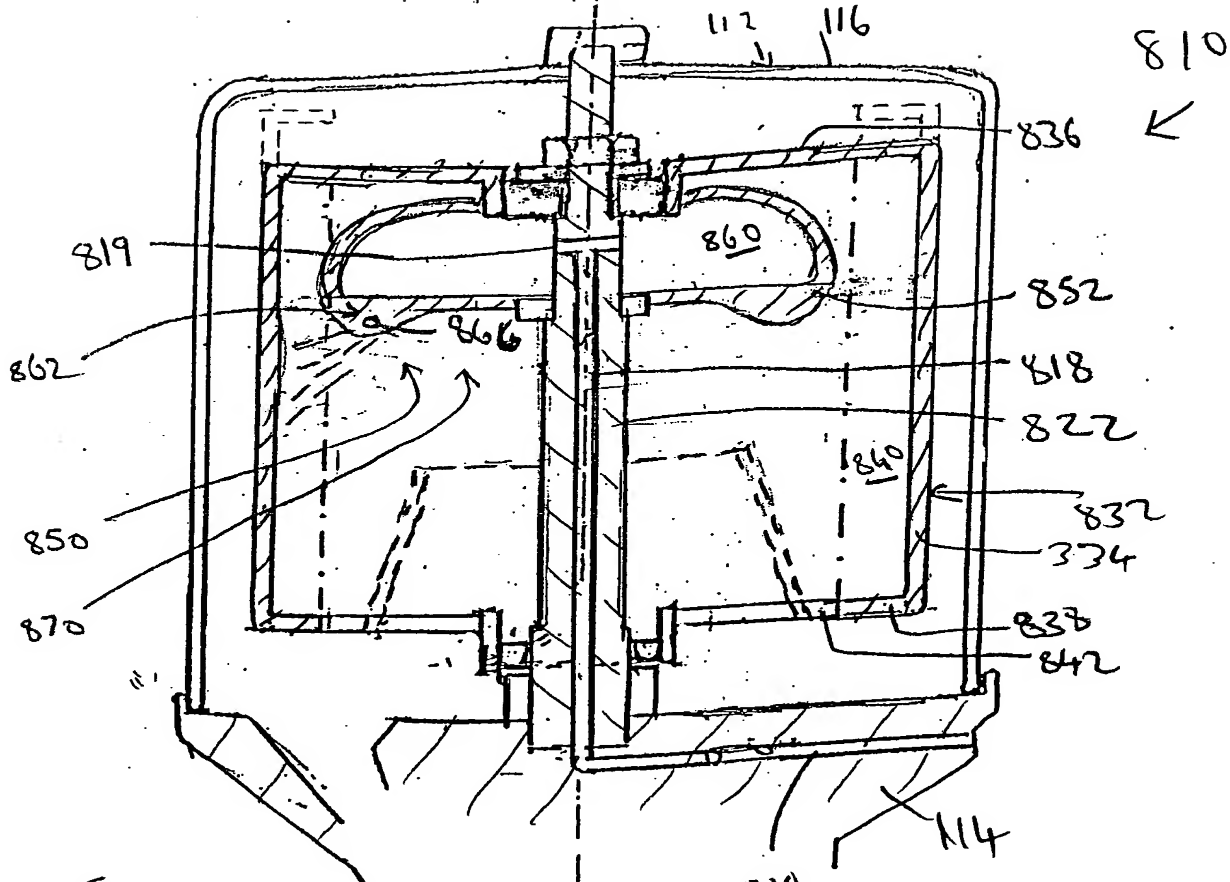
FIG 7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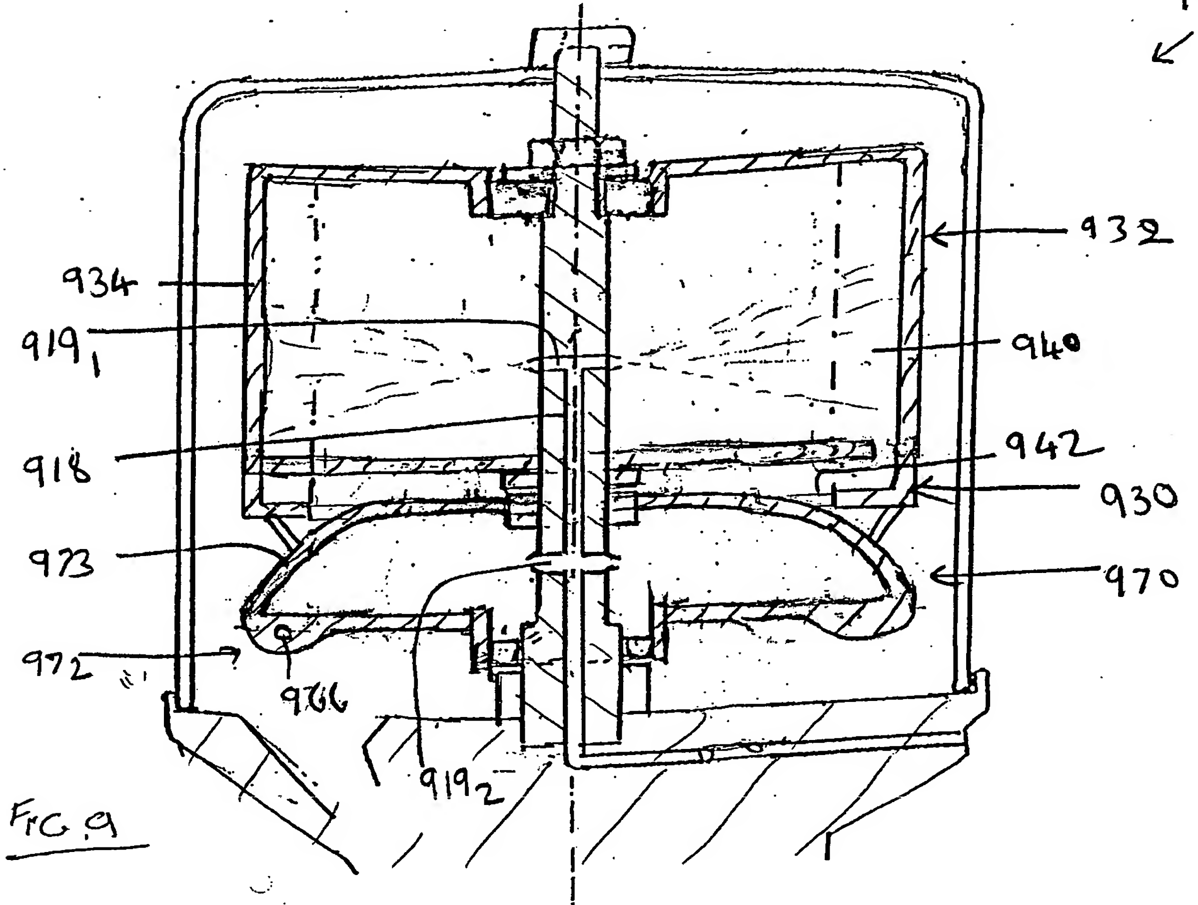
818

FIG.8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919

FIG.9

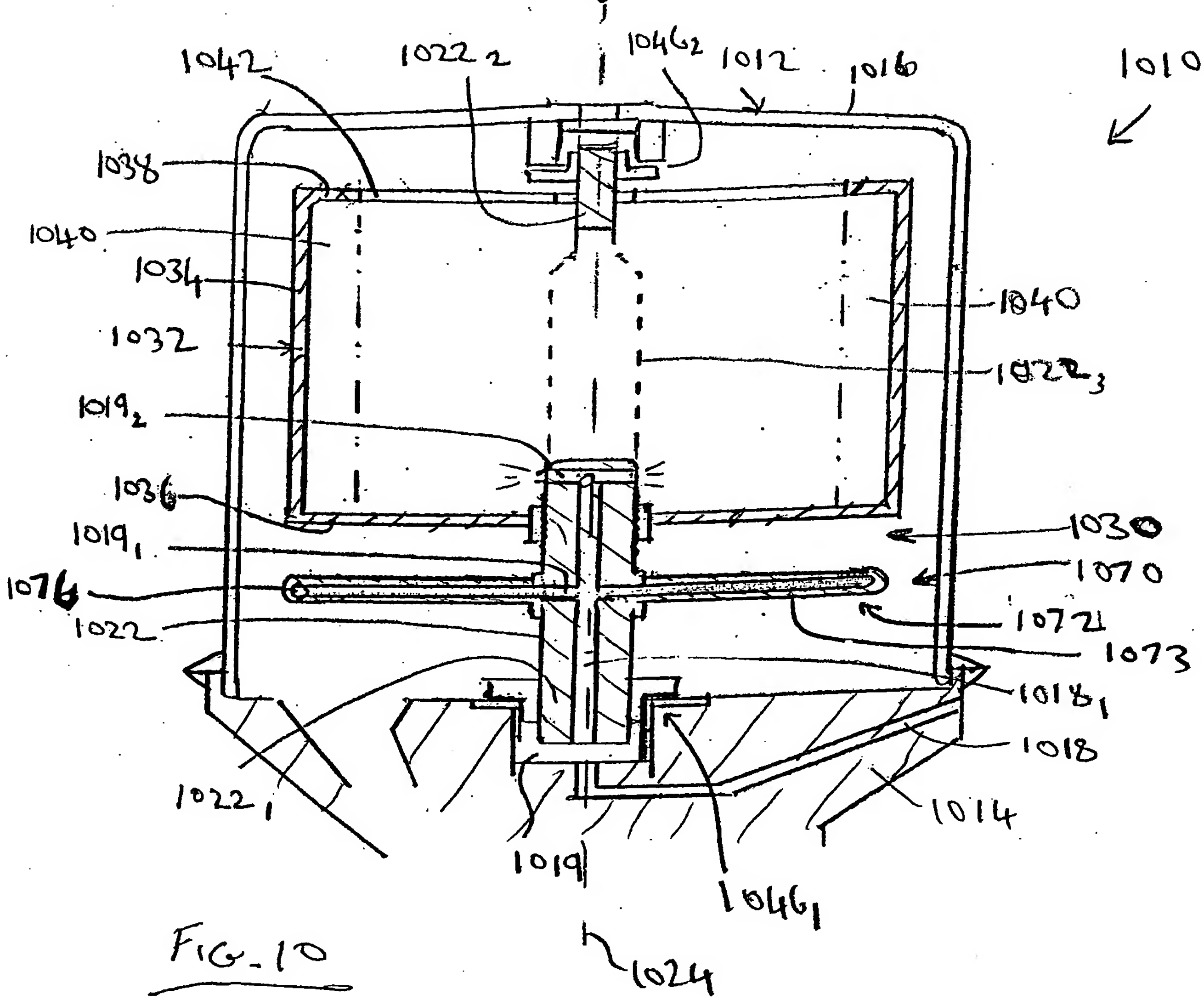

FIG. 10

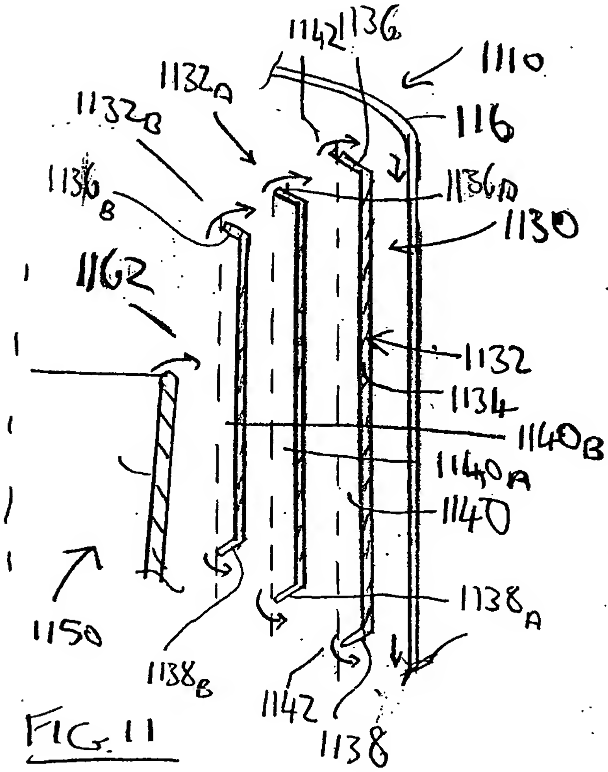

FIG. 11

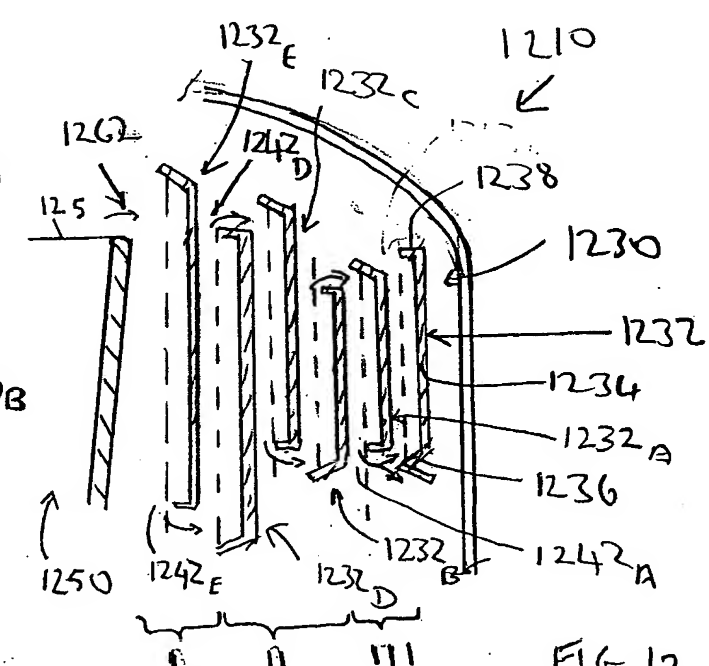

FIG. 12

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